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Embed Size (px) 344 x 292429 x 357514 x 422599 x 487 1. Goldstein Classical Mechanics NotesMichael Good May 30, 20041 Chapter 1: Elementary Principles1.1Mechanics of a Single ParticleClassical mechanics incorporates special relativity. Classical refers to the con-tradistinction to quantum mechanics.Velocity: dr v= . dtLinear momentum: p = mv.Force:dp F= . dtIn most cases, mass is constant and force is simplied:d dvF= (mv) = m= ma.dtdtAcceleration: d2 ra=. dt2 Newtons second law of motion holds in a reference frame that is inertial orGalilean.Angular Momentum: L = r p.Torque: T = r F.Torque is the time derivative of angular momentum: 1 2. dLT= .dt Work:2W12 = F dr.1 In most cases, mass is constant and work simplies to: 22 2 dvdvW12 = m vdt = m vdt = mv dv1dt 1dt 1 m 2 2W12 = (v2 v1) = T2 T1 2 Kinetic Energy: mv 2T =2 The work is the change in kinetic energy. A force is considered conservative if the work is the same for any physicallypossible path. Independence of W12 on the particular path implies that thework done around a closed ciruit is zero: F dr = 0 If friction is present, a system is non-conservative. Potential Energy: F = V (r).The capacity to do work that a body or system has by viture of is positionis called its potential energy. V above is the potential energy. To express workin a way that is independent of the path taken, a change in a quantity thatdepends on only the end points is needed. This quantity is potential energy.Work is now V1 V2 . The change is -V. Energy Conservation Theorem for a Particle: If forces acting on a particleare conservative, then the total energy of the particle, T + V, is conserved. The Conservation Theorem for the Linear Momentum of a Particle statesthat linear momentum, p, is conserved if the total force F, is zero. The Conservation Theorem for the Angular Momentum of a Particle statesthat angular momentum, L, is conserved if the total torque T, is zero.2 3. 1.2Mechanics of Many ParticlesNewtons third law of motion, equal and opposite forces, does not hold for allforces. It is called the weak law of action and reaction. Center of mass: mi rimi riR= =. mi MCenter of mass moves as if the total external force were acting on the entiremass of the system concentrated at the center of mass. Internal forces that obeyNewtons third law, have no eect on the motion of the center of mass. d2 R(e)F(e) M= Fi . dt2i Motion of center of mass is unaected. This is how rockets work in space. Total linear momentum:dridRP= mi =M. idt dtConservation Theorem for the Linear Momentum of a System of Particles:If the total external force is zero, the total linear momentum is conserved.The strong law of action and reaction is the condition that the internal forcesbetween two particles, in addition to being equal and opposite, also lie alongthe line joining the particles. Then the time derivative of angular momentumis the total external torque: dL = N(e) . dt Torque is also called the moment of the external force about the given point.Conservation Theorem for Total Angular Momentum: L is constant in timeif the applied torque is zero. Linear Momentum Conservation requires weak law of action and reaction. Angular Momentum Conservation requires strong law of action and reaction. Total Angular Momentum: L= ri pi = R M v +ri pi .i i3 4. Total angular momentum about a point O is the angular momentum of mo-tion concentrated at the center of mass, plus the angular momentum of motionabout the center of mass. If the center of mass is at rest wrt the origin then theangular momentum is independent of the point of reference. Total Work: W12 = T2 T11 2 where T is the total kinetic energy of the system: T = 2 i mi vi . Total kinetic energy: 1 2 11 T = mi vi = M v2 +mi vi2 . 2 i 22 iKinetic energy, like angular momentum, has two parts: the K.E. obtained ifall the mass were concentrated at the center of mass, plus the K.E. of motionabout the center of mass. Total potential energy: 1 V = Vi +Vij . i 2 i,j i=j If the external and internal forces are both derivable from potentials it ispossible to dene a total potential energy such that the total energy T + V isconserved.The term on the right is called the internal potential energy. For rigid bodiesthe internal potential energy will be constant. For a rigid body the internalforces do no work and the internal potential energy remains constant.1.3Constraints holonomic constraints: think rigid body, think f (r1 , r2 , r3 , ..., t) = 0, think a particle constrained to move along any curve or on a given surface. nonholonomic constraints: think walls of a gas container, think particle placed on surface of a sphere because it will eventually slide down part of the way but will fall o, not moving along the curve of the sphere.1. rheonomous constraints: time is an explicit variable...example: bead on moving wire2. scleronomous constraints: equations of contraint are NOT explicitly de- pendent on time...example: bead on rigid curved wire xed in space Diculties with constraints: 4 5. 1. Equations of motion are not all independent, because coordinates are no longer all independent2. Forces are not known beforehand, and must be obtained from solution.For holonomic constraints introduce generalized coordinates. Degrees offreedom are reduced. Use independent variables, eliminate dependent coordi-nates. This is called a transformation, going from one set of dependent variablesto another set of independent variables. Generalized coordinates are worthwhilein problems even without constraints. Examples of generalized coordinates:1. Two angles expressing position on the sphere that a particle is constrained to move on.2. Two angles for a double pendulum moving in a plane.3. Amplitudes in a Fourier expansion of rj .4. Quanities with with dimensions of energy or angular momentum. For nonholonomic constraints equations expressing the constraint cannot beused to eliminate the dependent coordinates. Nonholonomic constraints areHARDER TO SOLVE.1.4DAlemberts Principle and Lagranges EquationsDeveloped by DAlembert, and thought of rst by Bernoulli, the principle that: (a) dpi (Fi) ri = 0 idtThis is valid for systems which virtual work of the forces of constraint van-ishes, like rigid body systems, and no friction systems. This is the only restric-tion on the nature of the constraints: workless in a virtual displacement. Thisis again DAlemberts principle for the motion of a system, and what is goodabout it is that the forces of constraint are not there. This is great news, but itis not yet in a form that is useful for deriving equations of motion. Transformthis equation into an expression involving virtual displacements of the gener-alized coordinates. The generalized coordinates are independent of each otherfor holonomic constraints. Once we have the expression in terms of generalizedcoordinates the coecients of the qi can be set separately equal to zero. Theresult is: d T T{[( )] Qj }qj = 0 dt qj qj 5 6. Lagranges Equations come from this principle. If you remember the indi-vidual coecients vanish, and allow the forces derivable from a scaler potentialfunction, and forgive me for skipping some steps, the result is: d L L ( ) =0 dt qj qj1.5Velocity-Dependent Potentials and The Dissipation FunctionThe velocity dependent potential is important for the electromagnetic forces onmoving charges, the electromagnetic eld.L=T Uwhere U is the generalized potential or velocity-dependent potential.For a charge mvoing in an electric and magnetic eld, the Lorentz forcedictates: F = q[E + (v B)]. The equation of motion can be dervied for the x-dirction, and notice theyare identical component wise: m = q[Ex + (v B)x].x If frictional forces are present(not all the forces acting on the system arederivable from a potential), Lagranges equations can always be written: d L L ( ) = Qj . dt qj qj where Qj represents the forces not arising from a potential, and L containsthe potential of the conservative forces as before. Friction is commonly, Ff x = kx vx . Rayleighs dissipation function: 1 222Fdis =(kx vix + ky viy + kz viz). 2i The total frictional force is:Ff = v Fdis Work done by system against friction:dWf = 2Fdis dt 6 7. The rate of energy dissipation due to friction is 2Fdis and the component ofthe generalized force resulting from the force of friction is: FdisQj = . qj In use, both L and Fdis must be specied to obtain the equations of motion:d L L Fdis( ) = .dt qj qj qj 1.6Applications of the Lagrangian FormulationThe Lagrangian method allows us to eliminate the forces of constraint from theequations of motion. Scalar functions T and V are much easier to deal withinstead of vector forces and accelerations.Procedure:1. Write T and V in generalized coordinates.2. Form L from them.3. Put L into Lagranges Equations4. Solve for the equations of motion. Simple examples are:1. a single particle is space(Cartesian coordinates, Plane polar coordinates)2. atwoods machine3. a bead sliding on a rotating wire(time-dependent constraint).Forces of contstraint, do not appear in the Lagrangian formulation. Theyalso cannot be directly derived. 7 8. Goldstein Chapter 1 DerivationsMichael GoodJune 27, 20041 Derivations1. Show that for a single particle with constant mass the equation of motionimplies the follwing dierential equation for the kinetic energy:dT =Fvdtwhile if the mass varies with time the corresponding equation isd(mT) = F p.dtAnswer: dTd(1 mv 2) = 2 = mv v = ma v = F v dtdtwith time variable mass, d(mT)d p2= ( ) = p p = F p. dtdt 22. Prove that the magnitude R of the position vector for the center of mass froman arbitrary origin is given by the equation: 1 M 2 R2 = M2 mi ri 2 mi mj rij . i 2 i,jAnswer:MR = mi ri 1 9. M 2 R2 =mi mj ri rj i,j Solving for ri rj realize that rij = ri rj . Square ri rj and you get2 2 2 rij = ri 2ri rj + rj Plug in for ri rj 1 2 2 2 ri rj =(r + rj rij) 2 i 111M 2 R2 =2 mi mj ri +2mi mj rj 2mi mj rij 2 i,j2 i,j2i,j 1 11 M 2 R2 =M2 mi r i + M2 mj rPage 2 Frequently asked questions What are Chegg Study step-by-step Classical Mechanics Solutions Manuals? 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